



OPERATING AND SERVICE MANUAL

MODEL 431B

POWER METER

SERIALS PREFIXED: 301-, 233-, & 221-

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1501 PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.



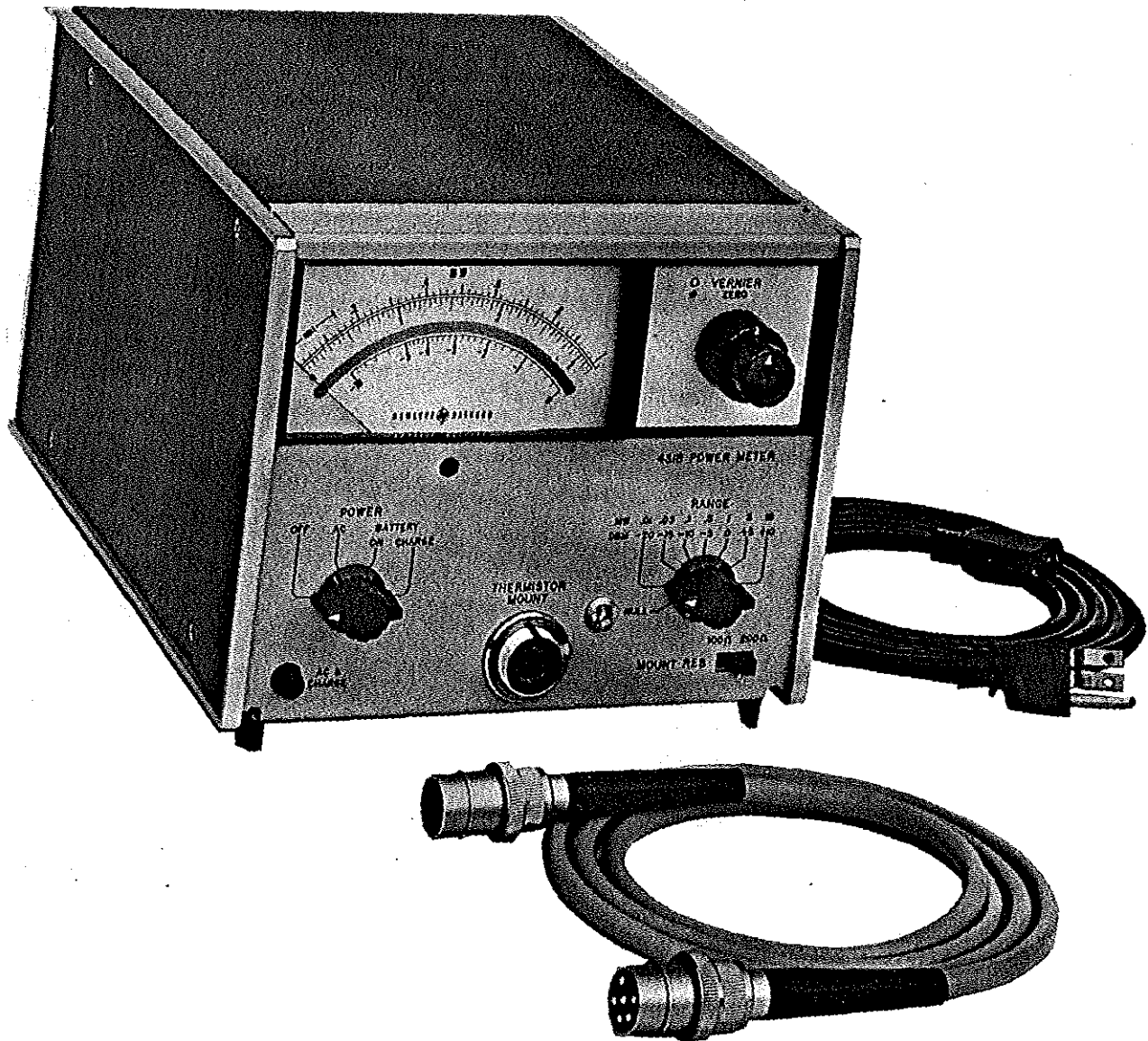


Figure 1-1. Model 431B Power Meter

SECTION I

GENERAL INFORMATION

1-1. DESCRIPTION.

1-2. The $\odot$ Model 431B Power Meter, with $\odot$ temperature compensated thermistor mounts, measures rf power from 10 microwatts (-20 dbm) to 10 milliwatts ($+10$ dbm) in the 10-mc to 40-gc frequency range. Direct reading accuracy of the instrument is $\pm 3\%$ of full scale. Instrument specifications are given in table 1-1.

1-3. The design of the Model 431B and its thermistor mount, results in almost complete freedom from measurement error caused by ambient temperature changes. The instrument incorporates two self-balancing bridges with one arm of each bridge being a thermistor. The two matched thermistors, both located within the mount, are thermally coupled, but

electrically isolated. One thermistor is used to absorb rf power; the other is used to provide temperature compensation. Thus, the thermal drift problems normally associated with the thermistor-power meter arrangement have been greatly reduced. A single setting of the ZERO control on the most sensitive power range is maintained within 1% for all higher power ranges.

1-4. The temperature compensated thermistor mounts used with the instrument are specifically designed for $\odot$ Model 431A/B Power Meters. Coaxial and waveguide thermistor mounts cover the 10-mc to 40-gc frequency range. Table 1-2 gives thermistor mount operating frequency, mount configuration, and operating resistance.

Table 1-1. Specifications

Instrument Type: Automatic, self-balancing for temperature compensated mounts	Weight: Net 8 lb (3.63 kg) with cover and cables 11-1/2 lb (5.44 kg) including battery; shipping approx. 13 lb (5.9 kg)
Power Ranges: 7 ranges with full scale readings of 10, 30, 100 and 300 μ w; 1, 3 and 10 mw. Also calibrated in dbm from -20 to $+10$.	Accessories Furnished: 5 ft (1.5 m) cable for $\odot$ temperature-compensated thermistor mounts. 7-1/2 ft (2.3 m) power cable, NEMA plug.
External Bolometer: Temperature-compensated thermistor mounts required for operation ($\odot$ 478A and 486A series).	Accessories Available: 431A-95B Rechargeable Battery Pack for field installation.
Accuracy: $\pm 3\%$ of full scale from $+20^{\circ}\text{C}$ to $+35^{\circ}\text{C}$, $\pm 5\%$ of full scale from 0°C to $+55^{\circ}\text{C}$	$\odot$ Models 478A and 486A Thermistor Mounts $\odot$ Model 8402A Power Meter Calibrator $\odot$ Model H01-8401A Leveler Amplifier
Zero Carry-Over: Less than 1% of full scale when zeroed on most sensitive range	Options: 01. Rechargeable battery installed, provides up to 24 hours continuous operation, 02. Rear input connector wired in parallel with front panel input connector, 10. With 20 foot cable for 100 Ω or 200 Ω mount, 11. With 50 foot cable for 100 Ω mount, 12. With 100 foot cable for 100 Ω mount, 13. With 200 foot cable for 100 Ω mount, 21. With 50 foot cable for 200 Ω mount, 22. With 100 foot cable for 200 Ω mount, 23. With 200 foot cable for 200 Ω mount.
Recorder/Voltmeter Output: Phone jack on rear with 1 ma maximum into 1000 ohms $\pm 10\%$; one side grounded	
Calibration Input: Binding posts on rear for calibration of bridge with $\odot$ 8402A Power Meter Calibrator or precise dc standards	
Power Supply: 115 or 230 volts $\pm 10\%$, 50 to 1000 cps, 2-1/2 watts	
Dimensions: 6-17/32 in. (166 mm) high, 7-25/32 in. (198 mm) wide, 12-1/2 in. (318 mm) deep	

Table 1-2. Model 431B Thermistor Mounts

Type		Frequency Range	Operating Resistance in ohms
Coaxial	Waveguide		
Ⓢ 478A		10 mc to 10 gc	200
	Ⓢ S486A	2.6 to 3.95 gc	100
	Ⓢ G486A	3.95 to 5.85 gc	100
	Ⓢ J486A	5.3 to 8.2 gc	100
	Ⓢ H486A	7.05 to 10.0 gc	100
	Ⓢ X486A	8.2 to 12.4 gc	100
	Ⓢ M486A	10.0 to 15.0 gc	100
	Ⓢ P486A	12.4 to 18.0 gc	100
	Ⓢ K486A Ⓢ K486AC*	18.0 to 26.5	200
	Ⓢ R486A Ⓢ R486AC*	26.5 to 40.0	200
* With circular contact flange adapter			

1-5. The Model 431B has provisions for using the dc substitution method of measurement and for checking calibration accuracy of the power meter. The dc substitution method of measurement which requires other equipment provides greater power measurement accuracies than can be obtained by the power meter

alone. In addition a jack in series with the panel meter permits digital or chart recording of measurements, operation of alarm or control systems and use in a closed-loop leveling system.

1-6. ACCESSORIES.

1-7. Two accessories are supplied with the Model 431B Power Meter: a 7-1/2-foot, detachable power cable and a 5-foot cable that connects the thermistor mount to the Model 431B. Thermistor mounts are available (see table 1-2) but not supplied with the instrument. A rechargeable battery with installation kit is also available. A list of supplied and available accessories is given in table 1-1, Specifications.

1-8. INSTRUMENTS WITH OPTIONS.

1-9. The options available with the Model 431B Power Meter are given in table 1-1. The thermistor mount cable options require modification and recalibration of the Model 431B Power Meter. The recalibration procedures for the cables are given in section V, Maintenance, under Oscillator Frequency Adjustment (paragraph 5-58) and Coarse Null Adjustment (paragraph 5-63).

1-10. INSTRUMENT IDENTIFICATION.

1-11. Hewlett-Packard uses a two-section eight-digit serial number (000-00000). If the first three digits of the serial number on your instrument do not agree with those on the title page of this manual, change sheets supplied with the manual will define differences between your instrument and the Model 431B described in this manual.

SECTION III

OPERATION

3-1. INTRODUCTION.

3-2. The Model 431B Power Meter measures rf power ranging from .01 to 10 milliwatts with power meter accuracy of $\pm 3\%$. Since the zero carries over within 1%, accuracies of at least $\pm 4\%$ can be obtained on any range by a single zeroing on only the lowest range.

3-3. MECHANICAL ADJUSTMENT OF METER ZERO.

3-4. The procedure for performing the mechanical adjustment of the meter zero is given in section V, paragraph 5-54.

3-5. CONTROLS AND INDICATORS.

3-6. The front and rear panel controls and connectors are explained in figure 3-1. The explanations are keyed to corresponding controls and indicator on the drawing of the front and rear panels of the instrument provided with the figure.

3-7. OPERATING INSTRUCTIONS.

3-8. Figure 3-2, Turn-On and Nulling Procedure, and figure 3-3, DC Substitution Technique, give step-by-step instructions for operating the Model 431B. In figure 3-2, each step is numbered to correspond with numbers on the accompanying drawing of the power meter.

3-9. BATTERY OPERATION.

3-10. The following applies to power meters having a factory or a field-installed rechargeable nickel-cadmium battery. See figure 3-1, Turn-On and Nulling Procedure, for step-by-step instructions for operating the Model 431B from a battery.

3-11. BATTERY CHARGING TIMES.

3-12. The battery used in the Model 431B requires two hours of charge time for one hour of battery operation. When the battery is fully charged, the Model 431B can be continuously operated for 24 hours with 48 hours of charge time. However, it is recommended that battery operated instruments be operated for eight hour periods with a 16 hour recharge time. This makes the Model 431B available for portable use daily, yet maintains the battery at full charge.

3-13. BATTERY CHARGE CHECK.

3-14. Under normal conditions, a fully charged battery will start at approximately 27 volts and drop to about 22 volts after 24 hours of continuous use at room temperature.

a. Connect the Model 431B to ac primary power. Set POWER to AC and perform the turn-on and nulling

procedure given in figure 3-2. This will check for normal operation from ac primary power. If performance is normal proceed to step b.

b. Set POWER to BATTERY CHARGE: the AC CHARGE lamp will glow. Allow Model 431B to charge the battery for 48 hours. This will allow the battery to obtain a full charge.

c. After the recharge interval, set POWER to BATTERY ON. Since battery is now fully charged, you should be able to zero-set and null the meter (figure 3-2). If not the battery or battery charging circuit is at fault. Refer to Battery and Charging Checks paragraph 5-40.

3-15. MAJOR SOURCES OF ERROR, MICROWAVE POWER MEASUREMENTS.

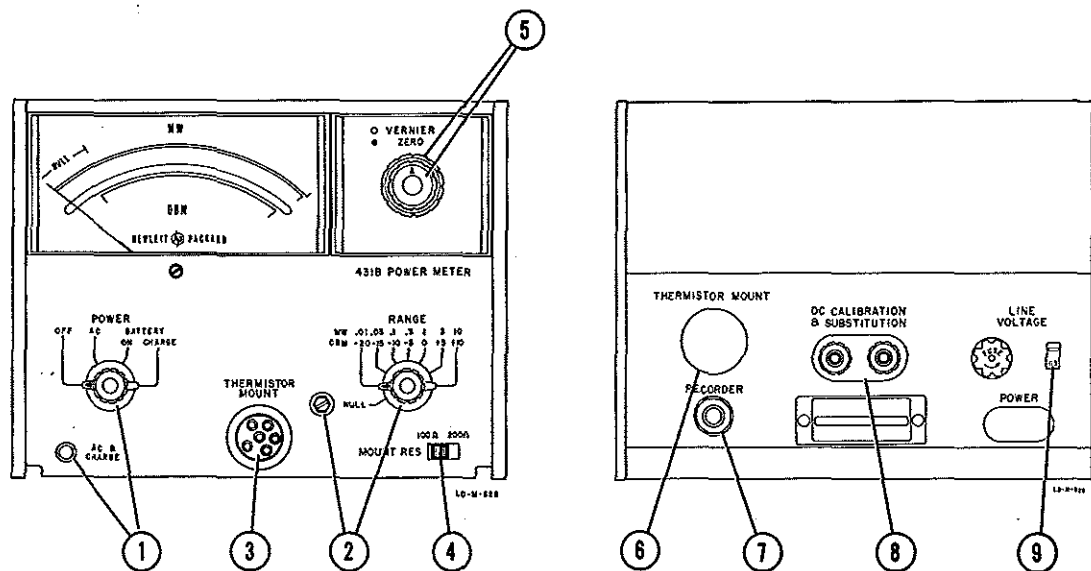
3-16. In microwave power measurements, the following are the major sources of error: 1) mismatch error or tuner loss (when a tuner is used to tune out mismatch error), 2) bolometer mount efficiency, 3) substitution error, 4) instrument error and 5) error due to the unilateral properties of a thermistor. Thus five errors must be known if accurate power measurements are to be obtained. Expressed mathematically:

Total measurement error =

mismatch (or tuner) loss + calibration factor + instrument error + error due to the unilateral properties of a thermistor

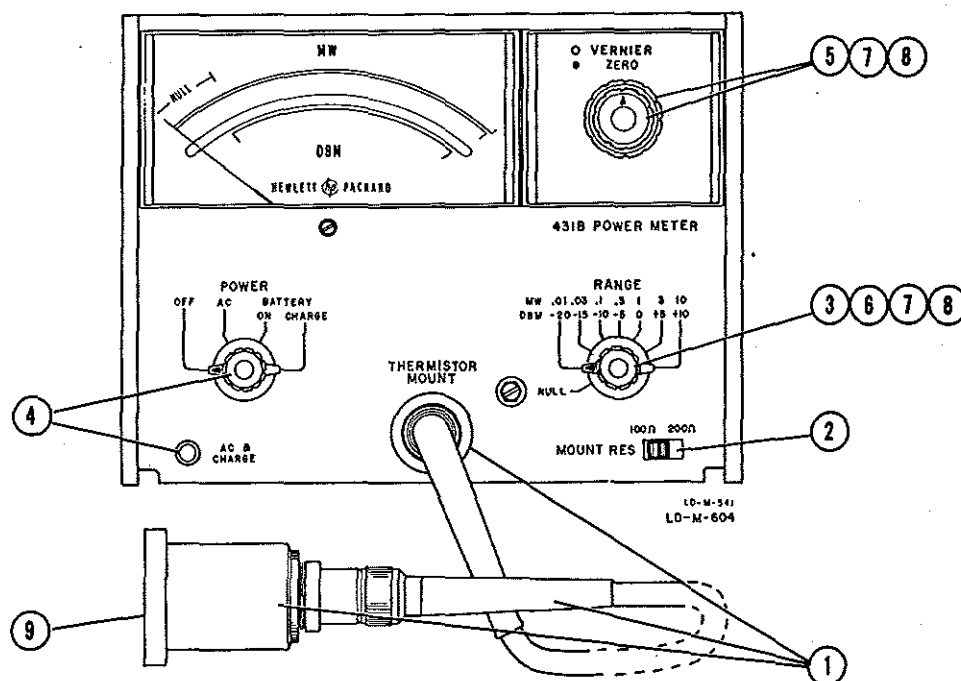
a. Mismatch Loss. Unless the mount and rf source are perfectly matched to the transmission system, a fraction of incident power is reflected and does not reach the thermistor. Since there generally is more than one source of mismatch in a microwave measurement system and the resulting error signals interact, loss cannot be calculated from the swr figure, it can only be expressed as lying between two limits. Limits of mismatch loss generally are determined by means of a chart such as the Mismatch Loss Limits chart included in each of the thermistor mount Operating Notes. A tuner such as the Model 872A or 870A can be used to minimize loss, although the tuner itself will introduce some loss.

b. Bolometer Mount Efficiency and Substitution Error. Not all the rf power applied to the mount is used to heat the rf thermistor. Some of it is absorbed by the other elements in the mount, such as the walls of the rf chamber, the heat sinks, the leads, etc. Substitution error results because rf power does not affect the thermistor to the same degree as dc power. Substitution error and mount efficiency are often combined for simplicity of measurement into what is termed "calibration factor". Typically, the calibration factor of the Model X486A waveguide mount is 97% to 98%.



1. **POWER:** The POWER switch sets up connections to the selected power sources or to the battery charging circuit. When the power switch is in the AC position, externally supplied 115 or 230 volts is applied to the instrument. If the instrument contains a battery, a trickle charge is applied to maintain the battery at full charge. With POWER at BATTERY ON, a 24-vdc battery within the instrument supplies primary power to the instrument. With POWER at CHARGE, 115- and 230-volt power is used to charge the battery (16 to 24 hours is required to obtain full battery charge). The instrument is inoperative in this position. Note: Batteries are installed at the factory for option 01 instruments only.
2. **RANGE:** The RANGE switch can be set for full scale power readings from .01 to 10 milliwatts in seven steps. It also includes a NULL position which, in conjunction with the adjacent null screwdriver adjust, insures that the metering bridge is reactively balanced.
3. **THERMISTOR MOUNT:** The THERMISTOR MOUNT connector is a female receptacle that accepts a specially-made cable which is supplied with the instrument. The cable connects the mount thermistors into their respective bridges within the power meter.
4. **MOUNT RES:** This two-position slide switch sets the power meter to accommodate thermistor mounts of 100- or 200-ohm nominal resistance.
5. **ZERO and VERNIER:** The ZERO control coarsely sets the meter pointer near zero; the VERNIER control is a more exact adjustment which sets the meter pointer on zero.
6. In Option 02 instruments only, mount connector wired in parallel with front-panel connector. Two mounts cannot be connected simultaneously.
7. **RECORDER:** The RECORDER input is a grounded telephone jack for monitoring the current which operates the Model 431B meter.
8. **DC CALIBRATION & SUBSTITUTION:** This terminal permits application of known direct current to the rf bridge. The power reading obtained with the accurately known dc power applied is then compared with the reading obtained when rf power was applied. The dc substitution technique is used both to calibrate the 431B and to increase the accuracy of power measurement.
9. **LINE VOLTAGE:** The LINE VOLTAGE switch, S1, is a two-position slide switch that selects the mode of ac operation. The line voltage for which the instrument is set to operate appears on the slider of the switch. A 15/100 slow-blow fuse is used for both 115 and 230 volt operation.

Figure 3-1. Front and Rear Panel Controls and Indicators



1. Connect thermistor mount and cable to the THERMISTOR MOUNT. ϕ thermistor mounts and their frequency ranges are given in table 1-2, Model 431B Thermistor Mounts.

Note

When possible, the Model 431B should be zeroed and nulled with the power source to be measured connected to the thermistor mount. If this is not possible, and a coaxial thermistor mount is used, terminate the rf input into a 50-ohm load. Power source should be off while zero and null-setting the Model 431B Power Meter.

2. Set MOUNT RES to match thermistor mount resistance (100 or 200 ohms).
3. Set RANGE to .01 MW.
4. Set POWER to AC; AC & CHARGE lamp will glow. If instrument is battery-operated, rotate POWER to BATTERY ON.
5. Adjust ZERO control for 25 to 75% of full scale on meter.
6. Rotate RANGE to NULL and adjust null screwdriver adjust (adjacent to NULL on RANGE switch) for a minimum reading.

7. Repeat steps 5 and 6 until NULL reading is within NULL region on the meter.

Note

If instrument is battery-operated and you are not able to zero the meter, or if meter pointer fluctuates rapidly, battery needs recharging. Refer to paragraph 3-11.

8. Set RANGE switch to the power range to be used and zero-set the meter with ZERO and VERNIER controls.

Note

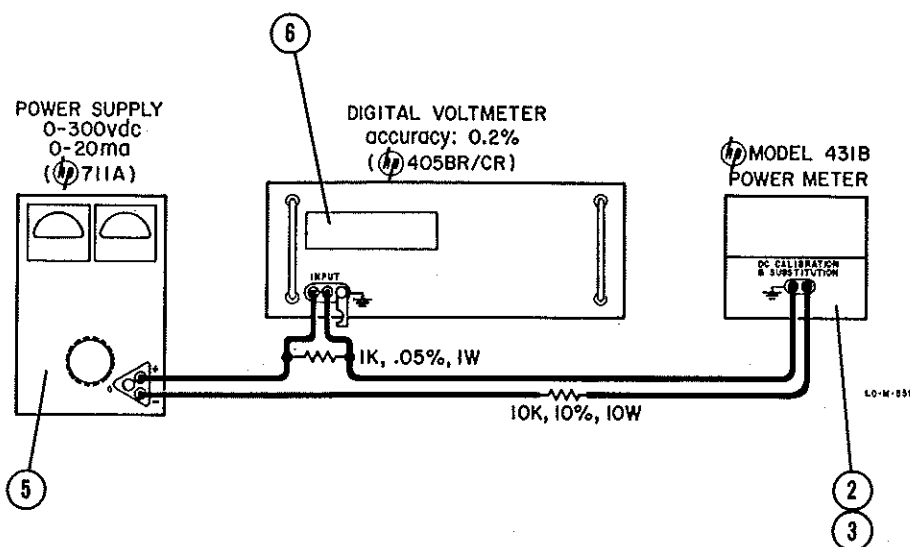
Zero-set accuracy of 1% can be obtained by zero setting the meter on the most sensitive range (.01 MW) only, and assuming the meter is properly zeroed on all less sensitive ranges. For maximum accuracy, zero set the meter on the range to be used.

9. Apply rf power at the thermistor mount and read power on Model 431B meter. Power is indicated on the meter directly in mw or dbm.

Note

This instrument is accurate to within $\pm 3\%$. Accuracy to $\pm 1\%$, or better, is possible using the dc substitution technique described in figure 3-3. See also paragraphs 3-15 and 3-17.

Figure 3-2. Turn-On and Nulling Procedure



1. With power supply turned off, connect the Model 431B as shown above.
2. Set the Model 431B for normal operation on the appropriate range using the procedure given in figure 3-2.
3. Apply rf power at the thermistor mount and note and record the reading of the Model 431B meter. This is the reference for the substitution measurement.

Note

A second digital voltmeter, in parallel with a 1000-ohm ($\pm 10\%$, 1 watt) resistor, connected in series with the RECORDER output of the Model 431B will increase accuracy of reference duplication.

4. Turn off, or disconnect, the rf source.
5. Turn power supply on; adjust the output voltage of the power supply until the reference of step 3 is duplicated. A potentiometer arrangement may be substituted for the adjustable power supply. However, at least 10,000 ohms must remain in series with the supply.

CAUTION

Never apply more than 20 ma dc to the DC CALIBRATION & SUBSTITUTION terminals of the Model 431B.

6. Read the voltmeter which monitors the substitution current. The voltmeter reading can be interpreted as current in milliamperes because the voltage is measured across 1000 ohms. This current is I_{dc} .

7. Calculate power in mw from the expression

$$\text{Power (MW)} = \frac{I_{dc}^2 R_d}{4 \times 10^3}$$

where R_d = operating resistance of the thermistor (100 or 200 ohms)

and I_{dc} = substitution current in milliamps (from step 6)

9. To minimize error due to drift in either the reference or substituted power level, steps 1 through 6 should be repeated.

Figure 3-3. DC Substitution Technique

c. **Instrument Error.** This is the inability of the power meter to accurately measure and interpret the information available at the thermistor element. In specifying the accuracy of a power meter, instrument error is the figure usually given. For the Model 431B, instrument error is $\pm 3\%$ of full scale, 20°C to 35°C . This error can be reduced by special techniques such as the dc substitution method discussed in para. 3-17.

d. **Error Due to the Unilateral Properties of a Thermistor.** The thermistor used in conjunction with the Model 431A/B exhibits unilateral properties which, when the source of power is a dc current, causes a slightly different indication of power than is obtained by the calculation of I^2R . Thus the dc power required to produce a reading on the Model 431A/B Power Meter is not the same as the rf power required to produce the same reading on the Model 431A/B Power Meter. The maximum error produced from this source of error is ± 0.3 μwatts , typical error is ± 0.1 μwatt . Since the order of magnitude of this error is small (0.3 μwatt) it need be minimized only on the two most sensitive ranges of the Model 431A/B Power Meter. Refer to the Φ Model 8402A Power Meter Calibrator manual for procedure used to minimize this error.

3-17. POWER METER ACCURACY OF 1% OR GREATER USING THE DC SUBSTITUTION METHOD.

3-18. Highly accurate instruments are available for measuring direct current. Thus, where optimum accuracy is required, there is considerable advantage in using a technique where the rf measurement is used only as a reference and the determination of rf power is based on precise dc measurements. In general the technique involves:

a. Applying rf power to the Model 431B in the usual manner, and noting the resulting meter indication for use as a reference.

b. Removing the rf power and applying sufficient dc at the DC CALIBRATION & SUBSTITUTION terminals to exactly duplicate the meter indication produced by the rf power.

c. Using the value of dc which duplicated the reference in calculating rf power.

3-19. Although the dc substitution technique is the most accurate method of measuring rf power, there are sources of error that must be considered. The accuracy of the dc substitution technique depends largely upon:

a. how precisely the reference is duplicated,

b. how accurately the value of the substituted dc is known,

c. the actual operating resistance of the thermistor, and

d. the actual ratio of current division in the rf bridge.

3-20. With precision components in the substitution setup and careful procedure, error produced by the Model 431B Power Meter can be reduced to 1% or less. This is assuming nominal thermistor mount resistance (100 or 200 ohms) and that half the applied dc flows through the rf thermistor. The dc substitution technique using the Model 431B is shown in figure 3-3.

3-21. EQUIPMENT USED FOR DC SUBSTITUTION.

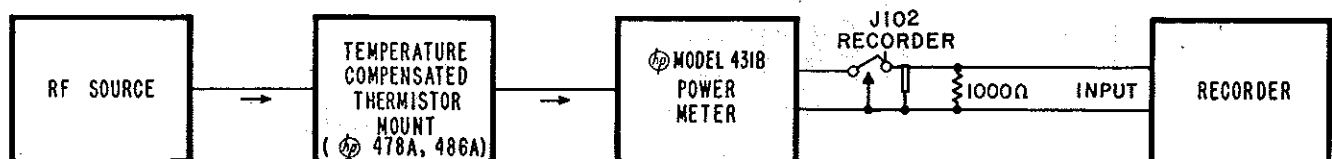
3-22. The Φ Model 8402A Power Meter Calibrator was specifically designed to be used for calibration and dc substitution measurements of rf power. In addition, the instrument will accurately measure the operating resistance of the thermistor mount being used. Use the procedures given in the manual provided with the Φ Model 8402A Power Meter Calibrator to perform the dc substitution measurements.

3-23. Although the most convenient and accurate means of applying the dc substitution technique is by using Φ Model 8402A Power Meter Calibrator, it is also possible to accurately measure power using the dc substitution technique with the arrangement shown in figure 3-3. The digital voltmeter is used to monitor the substitution current. The power supply output and voltmeter input are ungrounded to eliminate ground currents.

3-24. ADDITIONAL APPLICATIONS.

3-25. At the RECORDER output, the Model 431B furnishes a current (0 to 1 ma dc) which is proportional to the power measured. This feature makes possible a measurement system with more capability than simply the indication of power on a meter. Some of the more sophisticated measurement systems are shown in block diagram form in figures 3-4 through 3-8.

3-26. **PERMANENT RECORD.** Use of a recorder in the measurement system is indicated in figure 3-4. Resistance across the Model 431B RECORDER output should be 1000 ohms $\pm 10\%$ for optimum measurement accuracy. Any type of recorder may be used with the Model 431B; if input resistance exceeds 1000 ohms, use a shunt across the recorder input.



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Figure 3-4. Making a Permanent Record

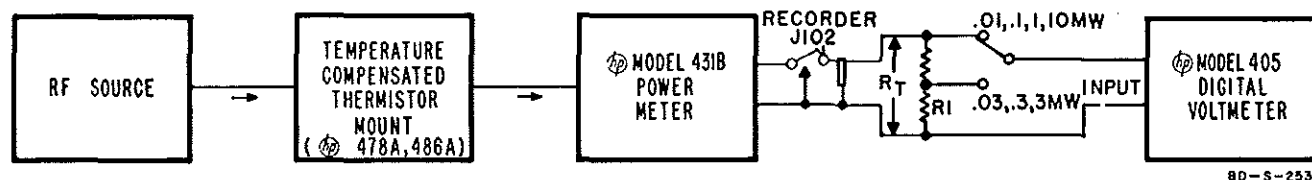


Figure 3-5. Obtaining Increased Resolution

3-27. INCREASED RESOLUTION. Digital readout of power to three decimal places can be obtained with the arrangement shown in figure 3-5. The value of R_I is 316.2 ohms $\pm 1\%$ and R_T is 1000 ohms $\pm 1\%$. Correct placement of the decimal in the readout is determined by the setting of the power meter RANGE switch. On the divider-switch arrangement at the voltmeter input may be replaced by a single 1000-ohm $.1\%$ resistor. With this arrangement, on the .01, .1, and 10 MW ranges, power is read in the same way as when the arrangement shown in figure 3-5 is used, decimal placement being determined by the setting of RANGE. On the .03, .3, and 3 MW ranges, however to obtain the power readings the voltmeter indication must be multiplied by the factor given in table 3-1.

Table 3-1. Voltmeter Readout to Power Multipliers

Range	Multiplier
.03 MW	0.0316
.3	0.316
3	3.16

3-28. LEVELER. Figure 3-6 is a block diagram of a closed-loop control circuit for maintaining output power at a constant level. It is recommended for use in leveling the output of various types of microwave equipment such as bwo sweep oscillators, twt microwave amplifiers, and rf generators. In addition to the

Model 431B and its thermistor mount, such a leveling system requires the H01-8401A Leveler Amplifier and a directional coupler with good directivity such as one of the 752 series of waveguide couplers or 760 series of coaxial couplers. The output of the power source is sampled by the coupler and applied to the Model 431B. A dc signal, proportional to the power sample, is fed (from the Model 431B RECORDER jack) to the Leveler Amplifier. In the H01-8401A the signal from the Model 431B is compared to an internal reference voltage, and the difference is amplified and fed back as a control voltage to hold output power constant.

3-29. MONITOR CONTROL SYSTEMS. By adding a dc amplifier and relay circuit to the rf monitoring arm of a system, the dc signal provided by the Model 431B can be used to actuate alarm or control circuits. Arrangement of equipment to provide an alarm or control system is shown in block diagram form in figure 3-7.

3-30. DETERMINING INSERTION LOSS OR GAIN AS A FUNCTION OF FREQUENCY. Arrangement of a system to obtain information on insertion loss or gain as a function of frequency is indicated in figure 3-8. Initially, the device under test is not connected into the system; connect the thermistor mount directly to the sweep oscillator. Set the sweep oscillator for the band of interest, and record variations in amplitude as frequency is swept; this curve is the reference. Next, insert the device under test between the sweep oscillator and the thermistor mount, and again record frequency response. The difference between the second reading and the reference, at any one frequency, is the insertion loss or gain of the device at that frequency.

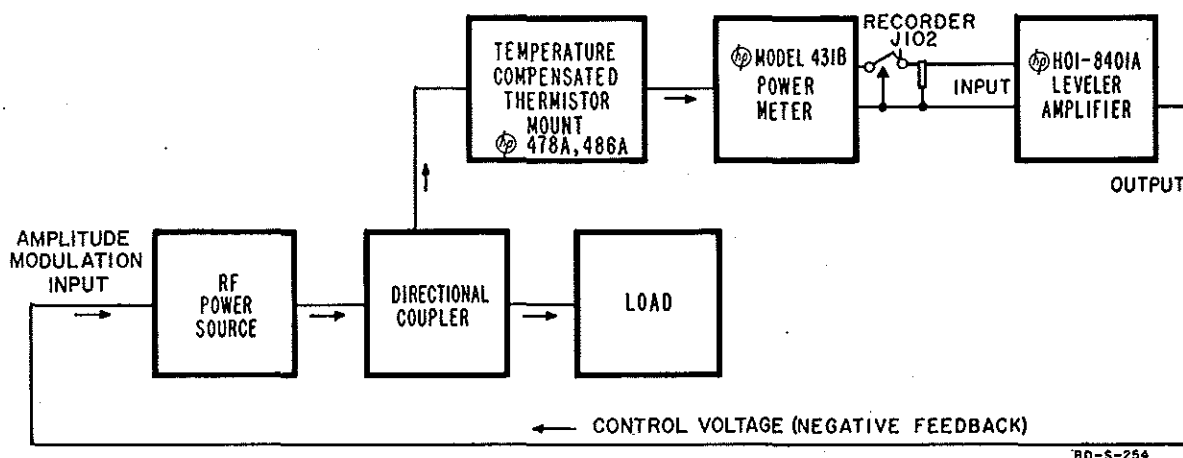


Figure 3-6. Leveler Setup

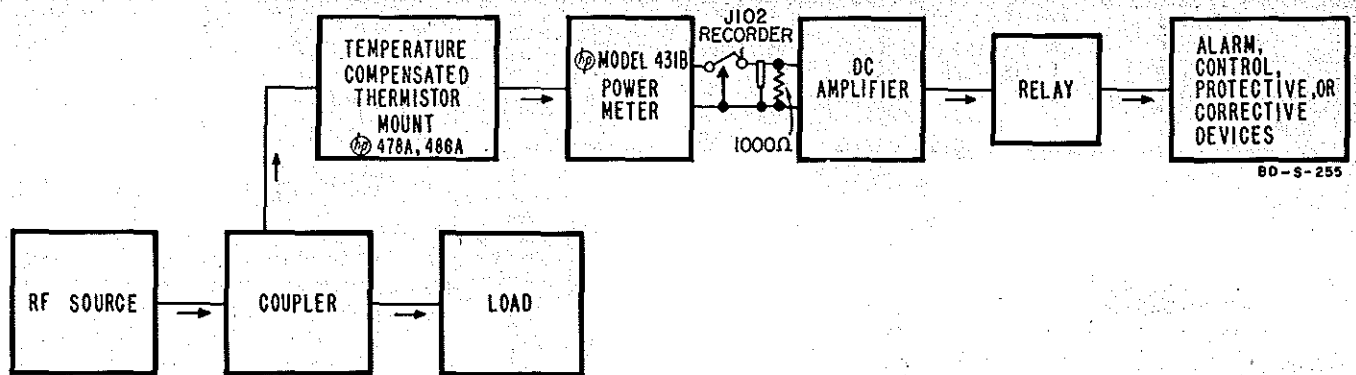


Figure 3-7. Monitoring Control Systems

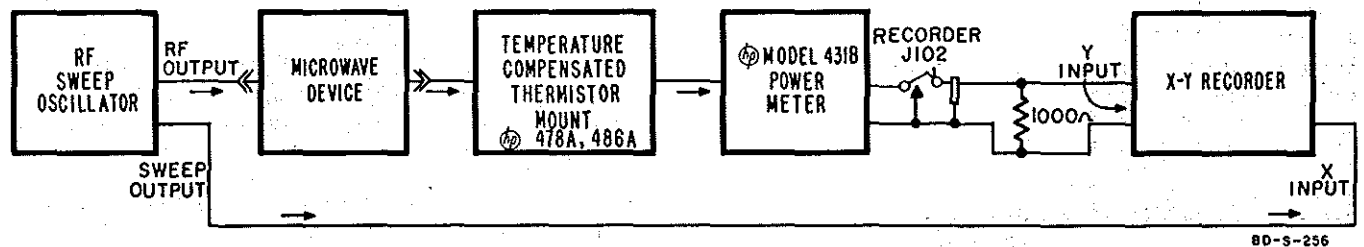


Figure 3-8. Determining Insertion Loss or Gain

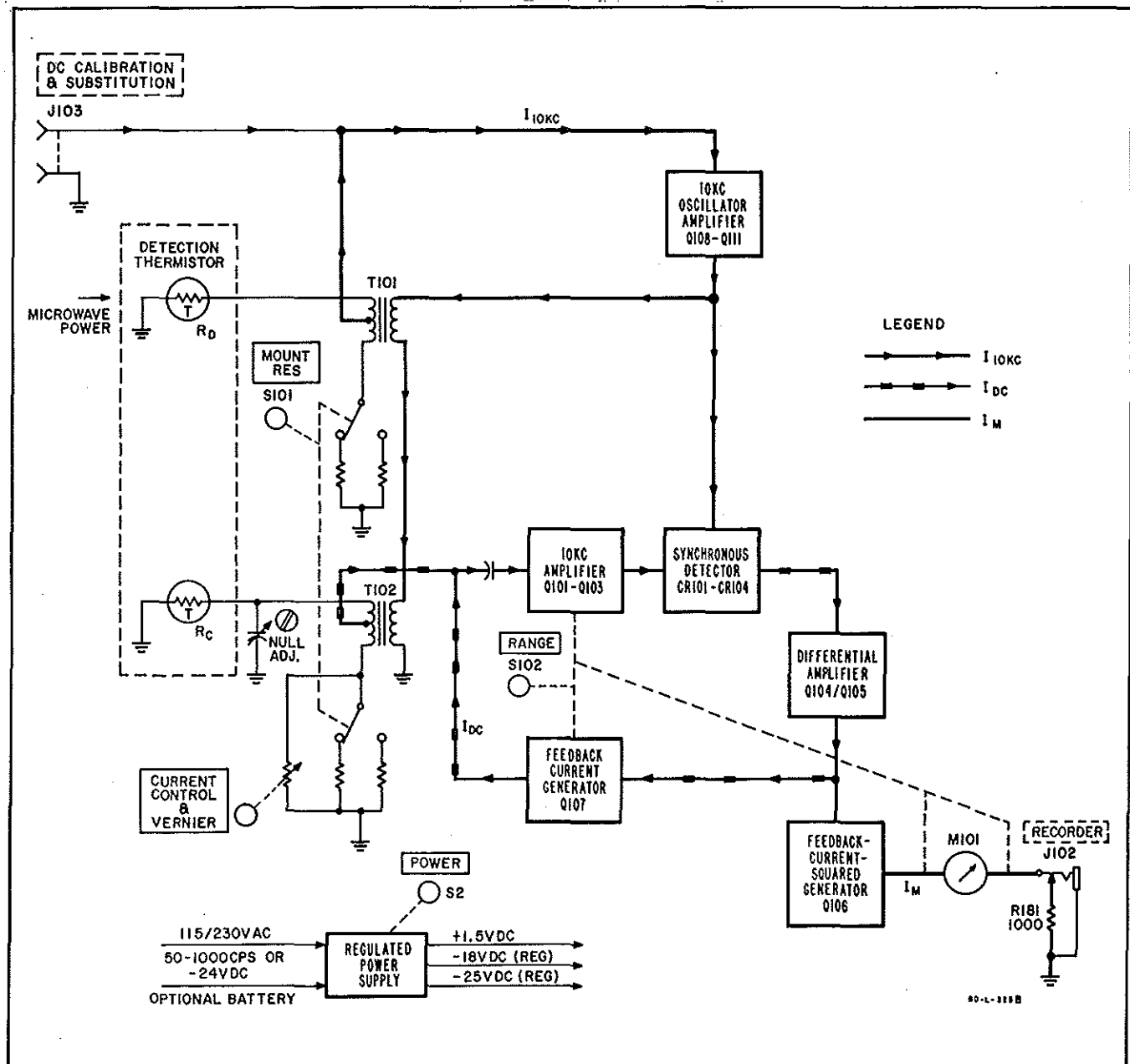


Figure 4-1. Block Diagram

SECTION IV

THEORY OF OPERATION

4-1. OVERALL DESCRIPTION.

4-2. Figure 4-1 is a block diagram which shows the Model 431B Power Meter and its associated thermistor mount. The thermistor mount contains two thermistor elements (R_d and R_c). Thermistor element R_d absorbs the rf power applied to the mount; thermistor element R_c converts the applied rf power to a meter indication and provides compensation for ambient temperature changes at the thermistor mount.

4-3. The power meter circuitry incorporates two bridges which are made self-balancing by means of separate feedback loops. Regenerative (positive) feedback is used in the detection loop; degenerative feedback in the metering loop. One thermistor element is used in one arm of each of the self-balancing bridges. In the detection loop, the 10 kc oscillator-amplifier supplies enough 10 kc power (I_{10kc}) to bias thermistor element R_d to the operating resistance which balances the rf bridge. The same amount of 10 kc power is also supplied to thermistor element R_c by the series-connected primaries of transformers T101 and T102.

4-4. When rf power is applied to thermistor element R_d , an amount of 10 kc power equal to the rf power is removed from thermistor element R_d by the self-balancing action of the rf bridge. Since the primaries of T101 and T102 are series-connected, the same amount of 10 kc power is also removed from thermistor element R_c , thus, the action which balances the rf bridge unbalances the metering bridge. The metering bridge loop automatically re-balances by substituting dc power for 10 kc power. Since the 10 kc power equaled the applied rf power, the substituted dc power is also equal to the applied rf power. Instead of metering the feedback current directly, which would require the use of a nonlinear meter scale, an analog current is derived which is proportional to the square of the feedback. Since power is a square-law function of current, the analog current thus derived is proportional to rf power, making possible the use of a linear scale on the meter.

4-5. There is little drift of the power meter zero point when ambient temperature at the thermistor mount changes. If, for example, ambient temperature at the mount increases, a decrease in electrical power to the thermistors is required to hold their operating resistances constant. The decrease, for both thermistors, is made automatically by the detection loop (figure 4-1) which reduces 10 kc power. The amount of dc power in the metering loop remains unchanged however, and since this dc power controls the meter action, the ambient temperature changes do not affect the meter indication. The compensation capability depends upon the match of thermistor temperature characteristics. When thermistor mounts are built, the thermistors are selected to insure optimum match of thermal characteristics.

4-6. CIRCUIT DESCRIPTION.

4-7. RF BRIDGE CIRCUIT.

4-8. A simplified schematic diagram of the rf bridge circuit is shown in figure 4-2. The rf bridge circuit consists of the rf bridge and 10-kc oscillator-amplifier. The rf bridge includes thermistor R_d , the secondary winding of T101, resistors R102 and R103, the MOUNT RES switch, S101, and capacitance represented by C_a and C_b . The rf bridge and 10 kc oscillator-amplifier are connected in a closed loop (the detection loop) which provides regenerative feedback for the oscillator-amplifier. This feedback causes the 10 kc oscillator-amplifier to oscillate.

4-9. When the power meter is off, thermistor R_d is at ambient temperature and its resistance is about 1500 ohms; the rf bridge is unbalanced. When the power meter is turned on this unbalance of the rf bridge causes a large error signal to be applied to the 10 kc oscillator-amplifier. Consequently maximum 10 kc bias voltage is applied to the rf bridge. As this 10 kc voltage biases R_d to its operating resistance (100 or 200 ohms) the rf bridge approaches a state of balance and regenerative feedback diminishes until there is just sufficient 10 kc bias power to hold R_d at operating resistance. This condition is equilibrium for the detection loop.

4-10. With application of rf power, thermistor R_d 's resistance decreases causing the regenerative signal from the rf bridge to decrease. Accordingly, 10 kc power diminishes, the thermistor returns to operating resistance and the detection loop regains equilibrium.

4-11. The MOUNT RES switch, S101, changes the resistance arm of the rf bridge so that the bridge will function with either a 100 or 200 ohm thermistor mount.

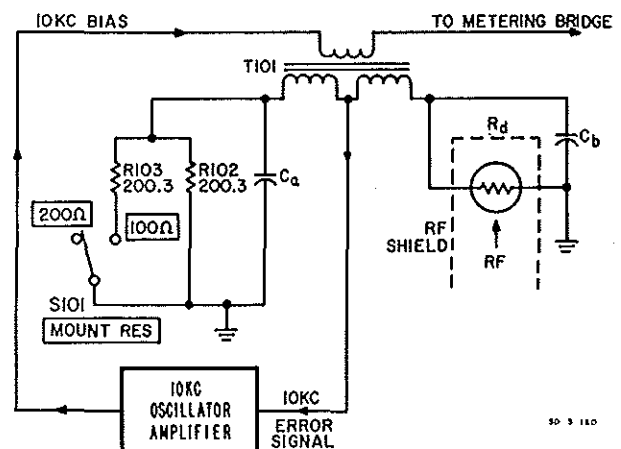


Figure 4-2. RF Circuit

4-12. METERING BRIDGE CIRCUIT.

4-13. A simplified schematic diagram of the metering bridge circuit is shown in figure 4-3. Operation of the metering bridge circuit is similar to the rf bridge circuit. It uses the same principle of self-balancing through a closed loop (metering loop). The major difference is that dc rather than 10-kc power is used to rebalance the loop. The resistive balance point is adjusted by the ZERO and VERNIER controls which constitute one arm of the bridge. The MOUNT RES switch (not shown in figure 4-3) which is mechanically linked to both the rf bridge and metering bridge, changes metering bridge reference resistance from 100 to 200 ohms. When the MOUNT RES switch is in the 200-ohm position some of the feedback current is shunted to ground through R101. This maintains the I^2R function constant when mount resistance is changed from 100 or 200 ohms. The switch also adds the necessary reactance for each position.

4-14. The same 10 kc power change produced in the rf bridge by rf power also affects the metering bridge through the series connection of T101 and T102 primaries. Although this change of 10-kc power has equal effect on both the rf and metering bridges, it is initiated by the rf bridge circuit alone. The metering bridge cannot control 10-kc bias power, but the 10-kc bias power does affect the metering circuit. Once a change in the 10-kc bias power has affected (unbalanced) the metering bridge, a separate, closed dc feedback loop (metering loop) re-establishes equilibrium in the metering circuit.

4-15. Variations in 10-kc bias level, initiated in the rf bridge circuit, cause proportional unbalance of the metering bridge, and there is a change in the 10-kc error signal ($S_{10\text{kc}}$) applied to the 10-kc tuned amplifiers in the metering loop. These error signal variations are amplified by three 10-kc amplifiers, and rectified by the synchronous detector. From the synchronous detector the dc equivalent (I_{dc}) of the 10-kc signal is returned to the metering bridge, and is monitored by the metering circuit to be indicated by the meter. This dc feedback to the metering bridge acts to return bridge to its normal, near-balance condition.

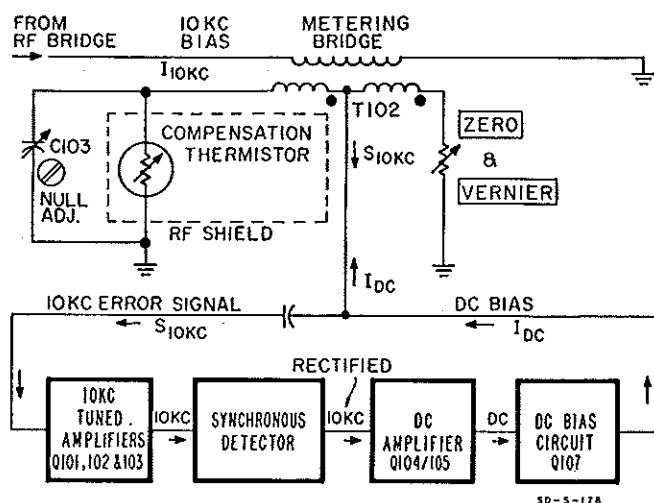


Figure 4-3. Metering Bridge Circuit

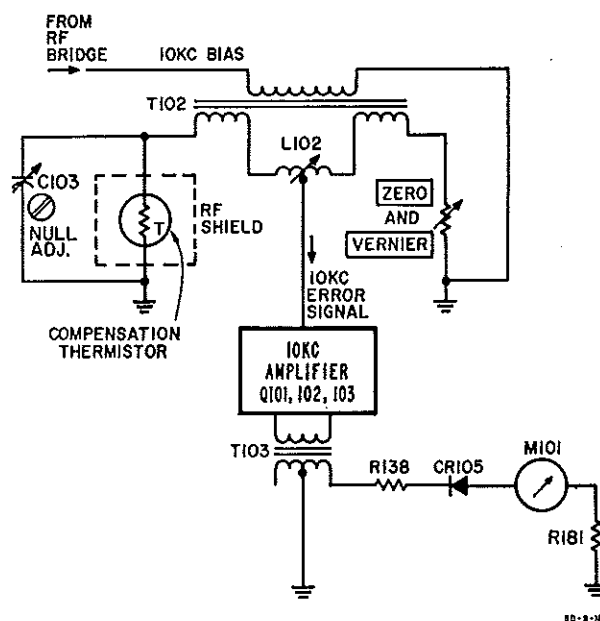


Figure 4-4. Nulling Circuit

4-16. The reactive components of the metering bridge are balanced with variable capacitor C103 and inductor L102. Null adjust, C103, is an operational adjustment and L102 is a maintenance adjustment. Null adjust C103, is adjusted with the RANGE switch in the NULL position. A simplified schematic diagram of the NULL circuit is shown in figure 4-4. The 10 kc signal is taken at the synchronous detector, rectified by CR105, and read on the meter. The rectified signal contains both reactive and resistive voltage components of the bridge unbalance.

4-17. SYNCHRONOUS DETECTOR.

4-18. The synchronous detector converts the 10-kc error signal from the metering bridge to a varying dc signal. A simplified schematic of the synchronous detector is shown in figure 4-5. The detector is a bridge rectifier which has a rectifier in series with a linearizing resistance in each of its arms. Two 10-kc voltages, designated E3 and E4 in figure 4-5, are applied to the bridge; 1) voltage E3, induced in the secondary of transformer T103, is proportional to the metering-bridge error signal and is incoming from 10-kc tuned amplifier Q103; 2) voltage E4, induced in the secondary of T104, is proportional to a voltage supplied by the 10-kc oscillator-amplifier. Voltage E4 is much larger than voltage E3 and switches appropriate diodes in and out of the circuit to rectify voltage E3. Section (a) of figure 4-5 shows the current path through diodes CR102 and CR104 for a positive-going signal; section (b) shows the current path through diodes CR101 and CR103 for a negative-going signal. The rectified output is taken at the center taps of transformers T103 and T104.

4-19. Operation of the circuit is as follows: When the left side of T104 is positive with respect to the right side as in figure 4-5a, diodes CR102 and CR104 conduct while diodes CR101 and CR103 are biased off. With the polarities reversed, as in figure 4-5b, the

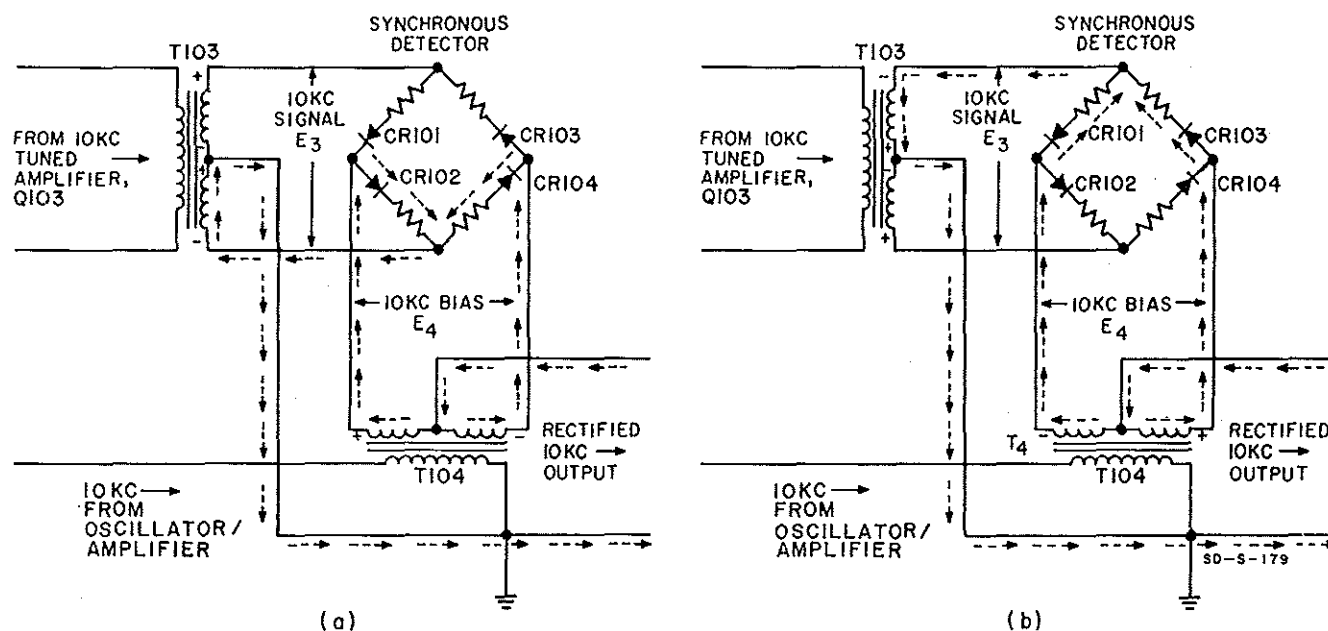


Figure 4-5. Synchronous Detector

diodes CR102 and CR104 are biased off. The resultant output is a pulsating dc signal equivalent to the applied 10-kc error signal. This pulsating dc signal is filtered and applied to differential amplifier Q104/Q105.

4-20. Proper synchronous detector output requires an in phase relationship between E3 and E4 and for amplitude of E4 to be larger than that of E3.

4-21. DIFFERENTIAL AMPLIFIER Q104/Q105.

4-22. A simplified schematic diagram of the amplifier is shown in figure 4-6. The pulsating dc from the synchronous detector is filtered by C117, C118, C119,

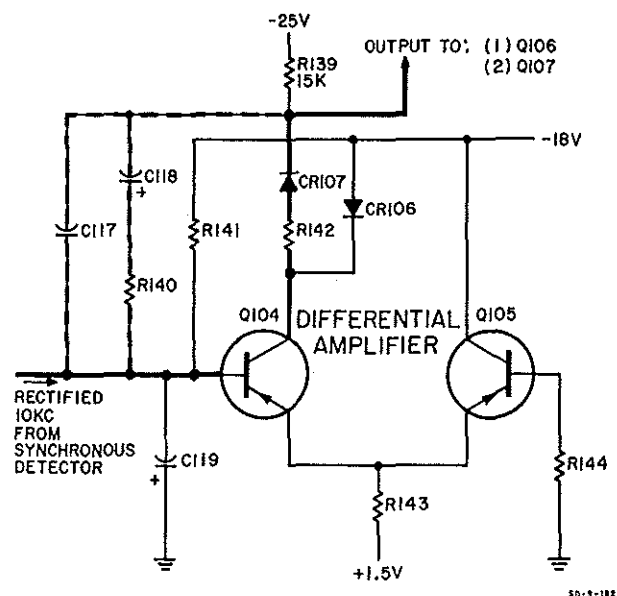


Figure 4-6. Differential Amplifier

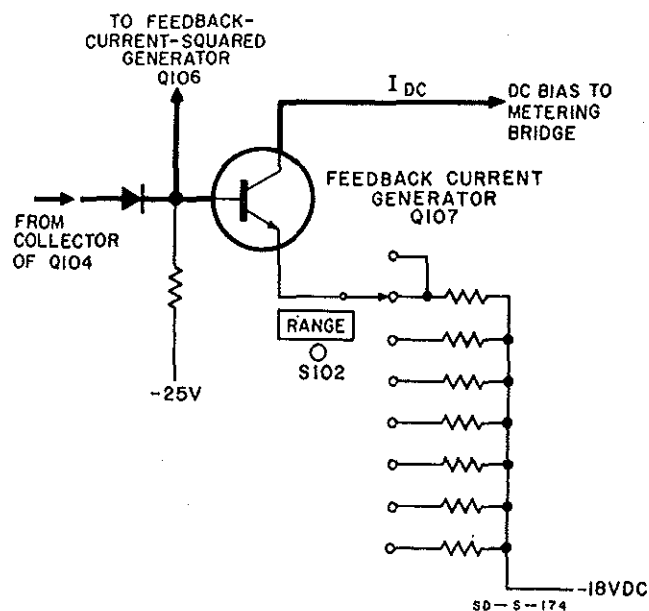


Figure 4-7. Feedback Current Generator

and R140, amplified by Q104 and fed to both the feedback current-squared generator, Q106 (figure 4-7) and feedback current generator Q107. Temperature compensation and low emitter circuit resistance for Q107 are provided by Q105. Diode CR106 protects Q106 and Q107 from excessive reverse bias when Q104 is cut off.

4-23. FEEDBACK CURRENT GENERATOR Q107.

4-24. A simplified schematic diagram of the feedback current generator is shown in figure 4-7. The dc signal from the differential amplifier is applied to feedback current generator Q107. Q107 has two functions: 1) it

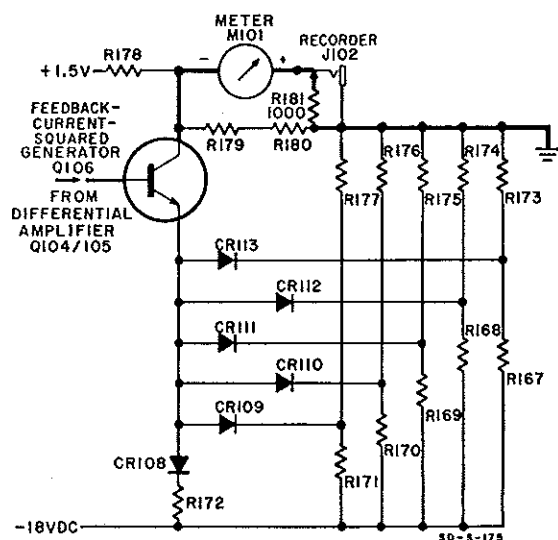


Figure 4-8. Meter Circuit

completes the metering loop to the metering bridge, and 2) it operates in conjunction with the first 10-kc amplifier, Q101, and the RANGE switch to change metering loop gain so that the meter will read full scale for each power range. Diode CR107 provides additional temperature compensation for Q107.

4-25. METER CIRCUIT.

4-26. The meter circuit is shown in figure 4-8. It includes feedback current-squared generator Q106, a squaring circuit, the meter, and RECORDER jack, J102. The purpose of the meter circuit is to convert a linear voltage function, proportional to applied power, to a squared function so that power may be indicated on a linear meter scale. The linear voltage function is applied to the base of Q106 and is converted to a square law function by the squaring circuit in series with Q106 emitter.

4-27. SQUARING CIRCUIT. The squaring circuit includes diodes CR109-113, and resistors R167-177. Temperature compensation for the squaring circuit is provided by CR108.

4-28. The design of the squaring circuit is such that individual diodes conduct at discrete values of emitter voltage so that emitter conductance approximates a square law function. Thus the collector current of Q106 is made to approximate a square law function, and the meter indicates power on a linear scale.

4-29. RECORDER OUTPUT. The current which drives the meter can be monitored at the RECORDER output, a telephone-type two-wire jack. A RESISTOR OF 1000 OHMS MUST REMAIN IN SERIES WITH THE METER FOR ALL APPLICATIONS USING THE METER-DRIVING CURRENT.

4-30. ZEROING. Perfect balance of the metering bridge would mean that no 10 kc error signal would be applied to the 10 kc amplifiers, there would be no dc feedback from Q107, and the metering loop would be open. With an open metering loop, zero reference could not be accurately established. In the Model

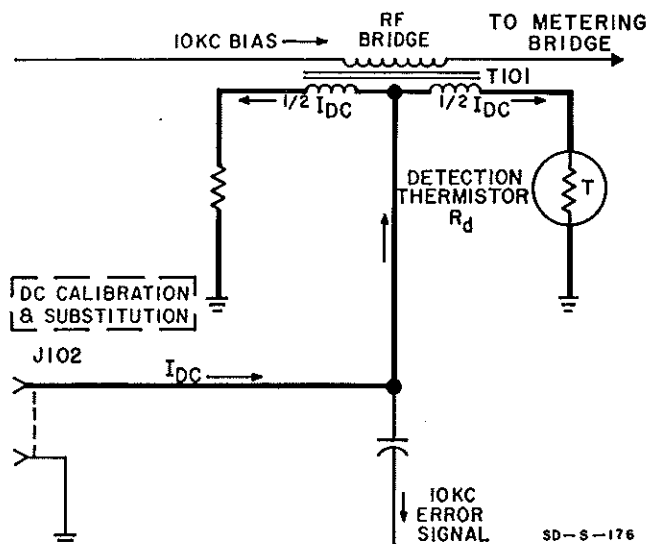


Figure 4-9. DC Calibration and Substitution

431B this occurrence is prevented by insuring a closed metering loop even when the ZERO control causes the meter pointer to deflect downscale from zero. By the combined actions of R141 and R179, the zero setting of the meter pointer does not coincide with absolute balance of the metering bridge. A slight unbalance of the bridge is maintained by R141, while R179 provides a counter-action in the feedback current-squared generator, Q106, so that the meter can indicate zero even though the metering bridge is not perfectly balanced. Resistor R179 also sets the full scale accuracy of the meter.

4-31. DC CALIBRATION AND SUBSTITUTION.

4-32. A simplified schematic diagram of the dc calibration and substitution circuit is shown in figure 4-9. Highly accurate rf power measurements can be made using the dc substitution technique given in figure 3-3. In the dc substitution method dc is used to duplicate the rf power reading. An accurate, known current (I_{dc}) is supplied externally at the DC CALIBRATION and SUBSTITUTION terminals. Calculation of the substituted dc power gives an accurate measure of the rf power. Effectively, dc power is substituted for rf power.

4-33. REGULATED POWER SUPPLY.

4-34. A simplified schematic diagram of the power supply is shown in figure 4-10. The power supply operates from either a 115 or 230 volt, 50 to 1000 cps ac source or from an optional 24 volt, 30 ma rechargeable battery. Three voltages and two current outputs are provided by the power supply. Regulated voltages of -18 and -25 vdc and unregulated +1.5 vdc operate the power meter circuits. The current outputs are used for maintaining battery charge (trickle charge) for recharging the battery.

4-35. The -18 vdc is regulated by a conventional series regulator, Q1 through Q5. The -25 vdc is developed across CR9, a 6.8 volt zener diode referenced at -18 vdc. The unregulated +1.5 vdc is taken

across the series diodes, CR5 and CR6. The -18 vdc supply is adjusted by R13.

4-36. POWER SWITCH.

4-37. A simplified schematic diagram of the power switching arrangement is shown in figure 4-11. The power switch, S2, has four positions: OFF, AC, BATTERY ON, and BATTERY CHARGE. In the AC position, the instrument operates from the conventional line voltage; if a battery has been installed in the instrument, a trickle charge is supplied to the battery. In the BATTERY ON position, instrument operation is entirely dependent on the battery. In the CHARGE position, -25 volts is connected to the battery for recharging; the Model 431B cannot be operated during this time. Approximately 37 ma dc is applied to the battery during charge time.

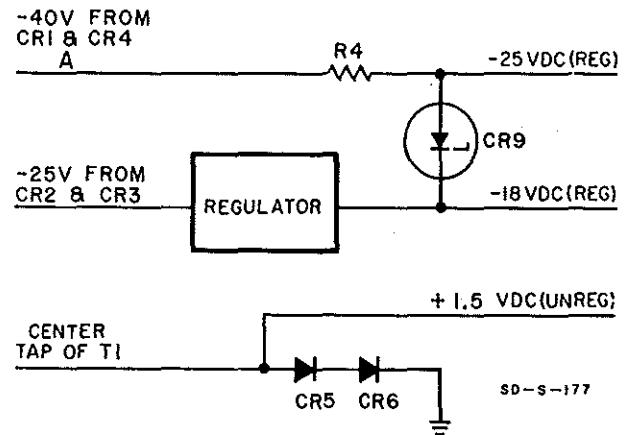


Figure 4-10. Regulated Power Supply

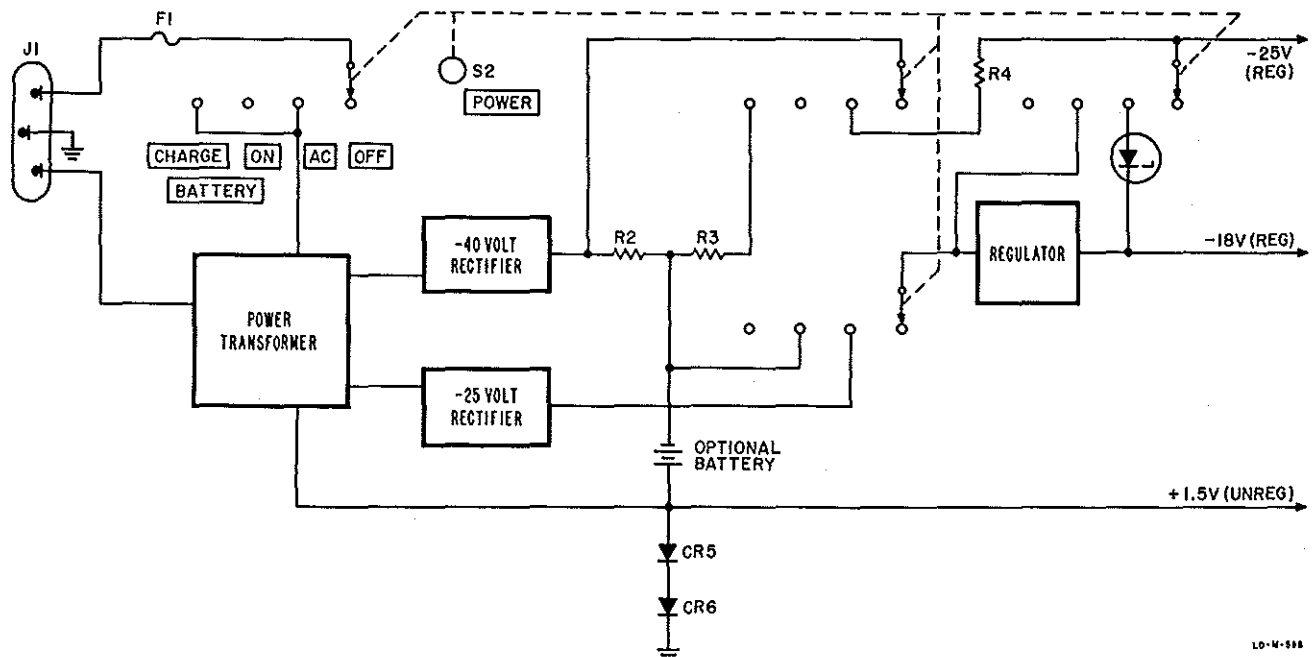


Figure 4-11. Power Switch Arrangement

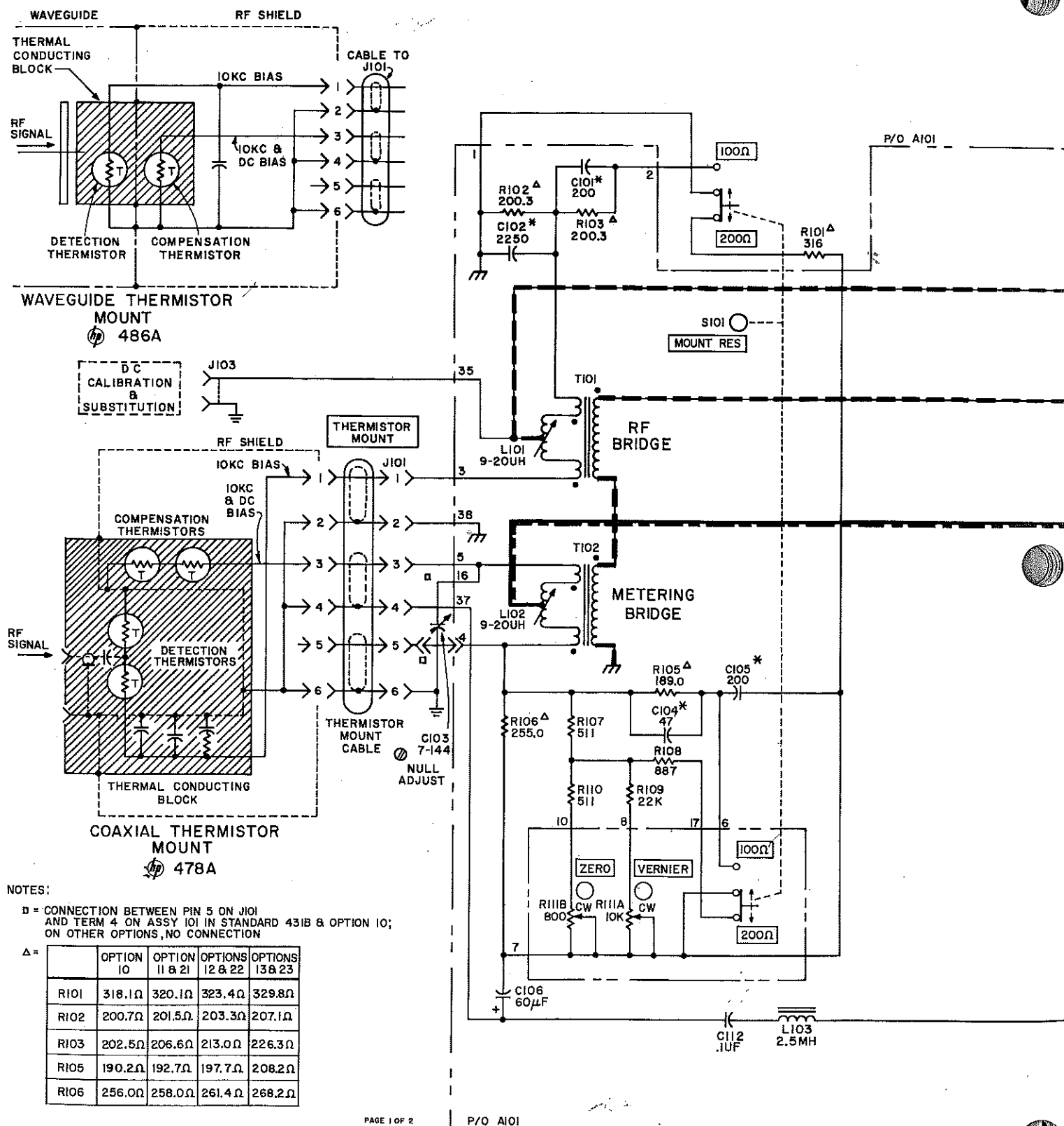


Figure 5-3. Power Meter Assembly

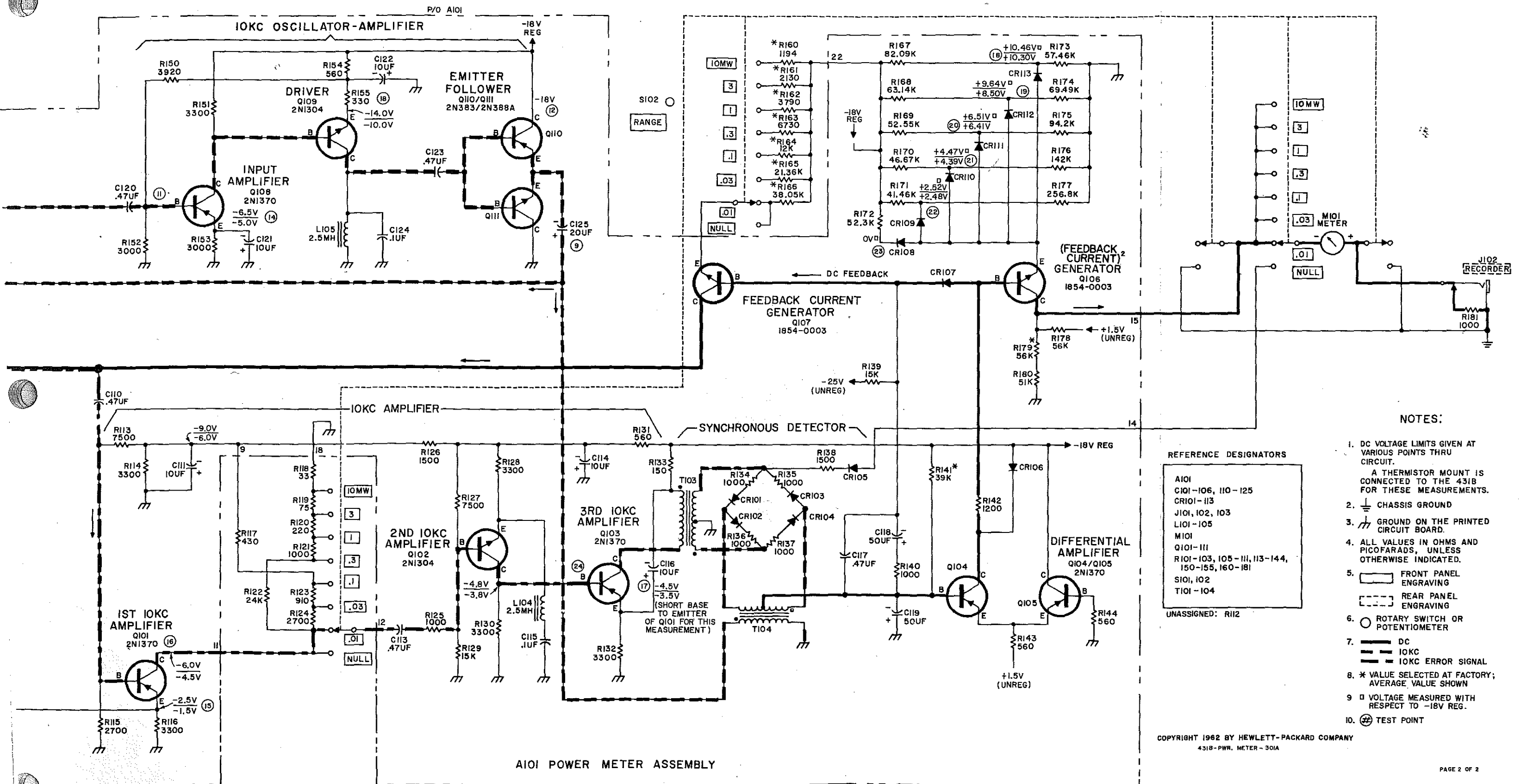


Figure 5-3. Power Meter Assembly